

REPORT

ON THE

SEISMIC AND VOLCANIC CENTERS

OF THE

PHILIPPINE ARCHIPELAGO.

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PREFACE.

The present paper contains some interesting data concerning the volcanology and seismology of the Philippine Islands; its object is similar to that which the Observatory had in view when it published the small pamphlets containing interesting meteorological and magnetic data of the Archipelago. We hope the interest excited by the present pamphlet will not be inferior to that of the preceding ones, and that it will satisfy the natural curiosity of many who, visiting these islands for the first time, and hearing much about their volcanoes and earthquakes, desire to obtain some reliable information regarding the seismic and volcanic manifestations of the Archipelago. This little work will be of utility also to those who wish to study these phenomena and have not at hand, or perhaps are unable to understand owing to their ignorance of the language, the Spanish publications issued by the seismic department of the Observatory. For such as these it will serve as a guide-book. A list of the above publications will be found on the last page of this paper, and should any of our readers desire fuller information on the subject of the seismology of the Philippines, they would do well to provide themselves with some of them, as the present paper is but a brief summary of their contents. Notwithstanding the imperfection of historical records relative to the earthquakes felt outside of Manila during the early years of the Spanish dominion, we are convinced that a brief summary of these records will be of interest to our readers, and they will be treated of in their proper place when we shall treat separately the various seismic and volcano-seismic centers of the Archipelago.

MANILA CENTRAL OBSERVATORY, *September, 1901.*

GENERAL IDEA OF THE SEISMIC SERVICE IN THE ARCHIPELAGO.

The founders of the Manila Observatory were soon convinced that, although the investigation of the earthquakes would not be so practical a study as that of the climatology of the Islands, it would, nevertheless, be one of great interest. Hence the study of earthquakes and of seismic phenomena at the Observatory dates almost from its foundation in the year 1865.

Little, however, could be done until much later, i. e., until the year 1884, when the Observatory was officially recognized by the Government, and a suitable number of meteorological stations were erected, which served at the same time as seismological stations. Up to that date the only seismic observations furnished to the Observatory were those made by private persons, especially by Jesuit missionaries. Hence it is evident that the data thus acquired, however certain they may be, can not be considered sufficient for formal seismological investigation. This same state of affairs was renewed in 1897-1901, owing specially to the unsettled state of the country, which up to the present has prevented the establishment by the Observatory staff of the new meteorological and seismological service under the auspices of the American Government. The first instruments used for the study of these seismic phenomena consisted of pendulums of very simple construction, for tracing the horizontal and vertical movements of the earth. Other instruments were acquired later on, both for direct observation and for recording purposes. Shortly after the great earthquake of 1880, which well-nigh laid the city of Manila in ruins, the Rev. P. Faura, the then Director of the Observatory, published a very interesting report on the same, and roused such interest in the subject among some of the more wealthy people of the city of Manila that by their aid it became possible for the Observatory to provide itself with better and more accurate seismic instruments, similar to those then in use in Italy. Hourly microseismic observations with Bertelli's microseismometer pendulum were commenced in January, 1883, and in 1887 the monthly review began to be illustrated with the monthly records of earthquakes, which are of such frequent occurrence in one part or another of this Archipelago. At this time also many observations came to hand from all parts of the islands, not only from the official stations, but also from private persons.¹ When the new meteor-

¹See "La seismologia en Filipinas," Plate I, p. 2.

logical service shall have been established throughout the Archipelago, the Central Observatory of Manila will have at its disposal ninety official earthquake stations, besides many other private ones. In the first, second, and third class official stations a seismographic pendulum will be erected.

The Central Observatory is at present furnished with the following instruments,¹ most of them being placed on the solid pier rising through the floors in the left tower of the main building:

INSTRUMENTS FOR DIRECT OBSERVATION.

Bertelli's horizontal microseismometer.

One vertical microseismometer.

Three ordinary seismometers; two for horizontal and one for vertical motion.

One pendulum for the direction of initial motion.

Two cryptophones; one of which has the surface of a paraboloid mathematically traced by the Dutch Jesuit Father Rankin, Assistant Director of Manila Observatory in 1886.

REGISTERING SEISMIC INSTRUMENTS.

Cecchi's microseismograph.

Cecchi's seismograph.

Rossi's microseismograph.

Gray-Milne's improved triple pendulum seismograph.

One vertical microseismograph.

Vincentini's improved microseismograph.

Necoman's improved self-recording tide gauge.

There are also several microseismographs in the astronomical building adjusted to the solid bases of the equatorial and transit telescopes.

¹Almost all these instruments are fully described in "La seismologia en Filipinas," pp. 4-16.

VULCANOLOGIC MAP

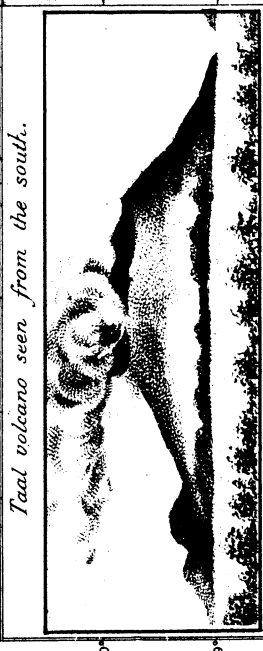
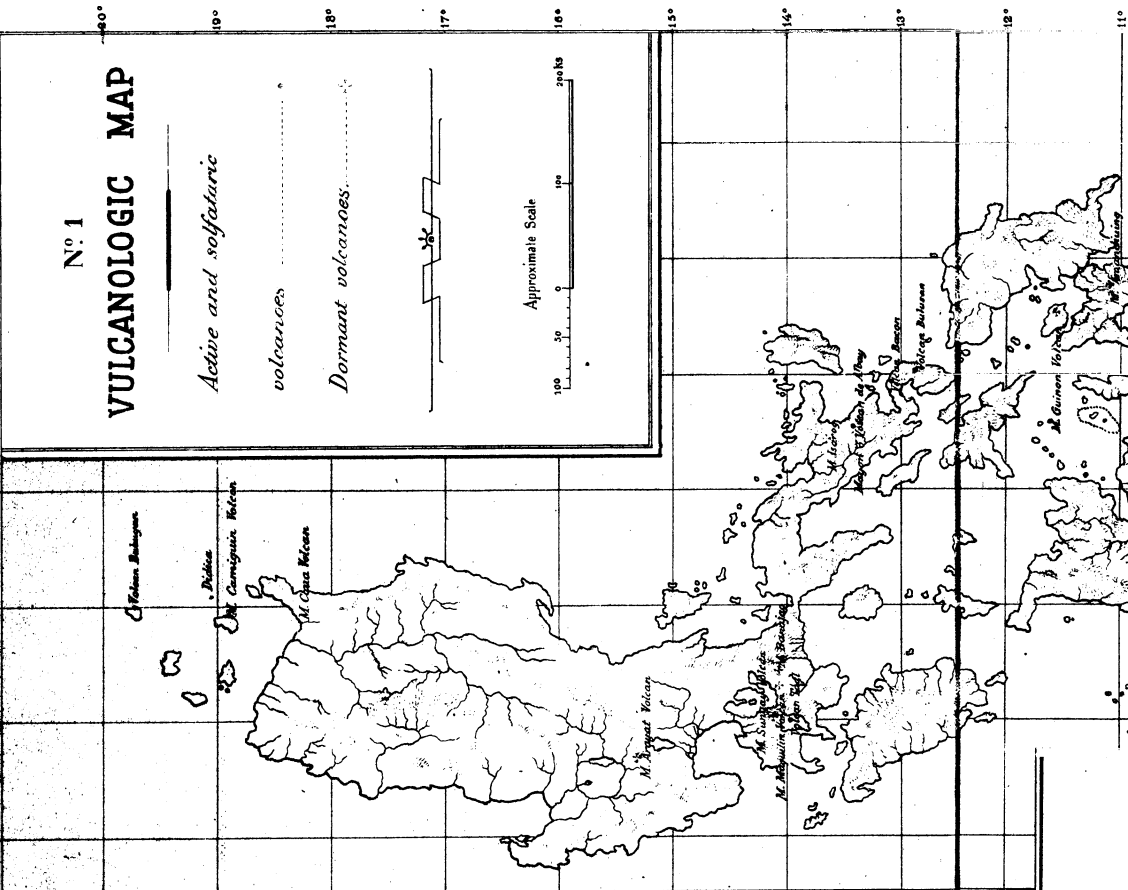
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Active and sofiataric

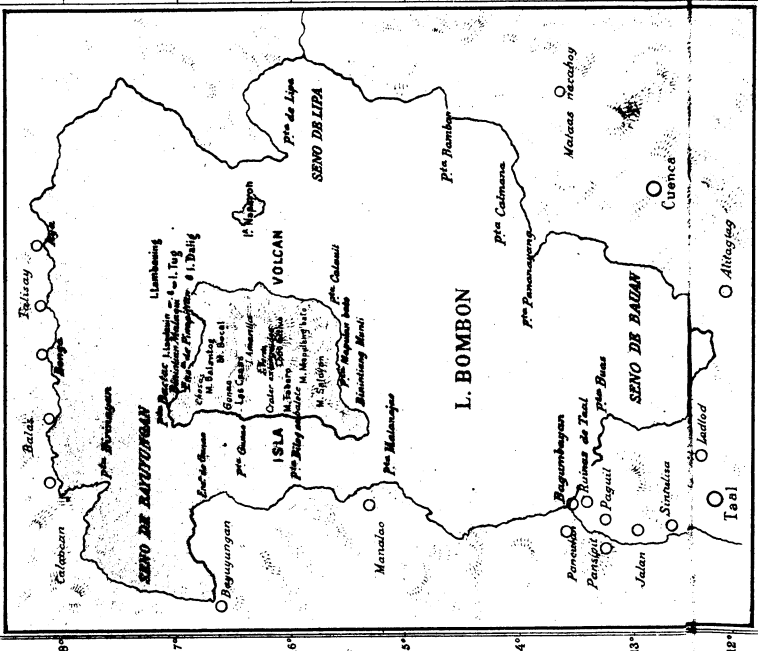
volcanoes

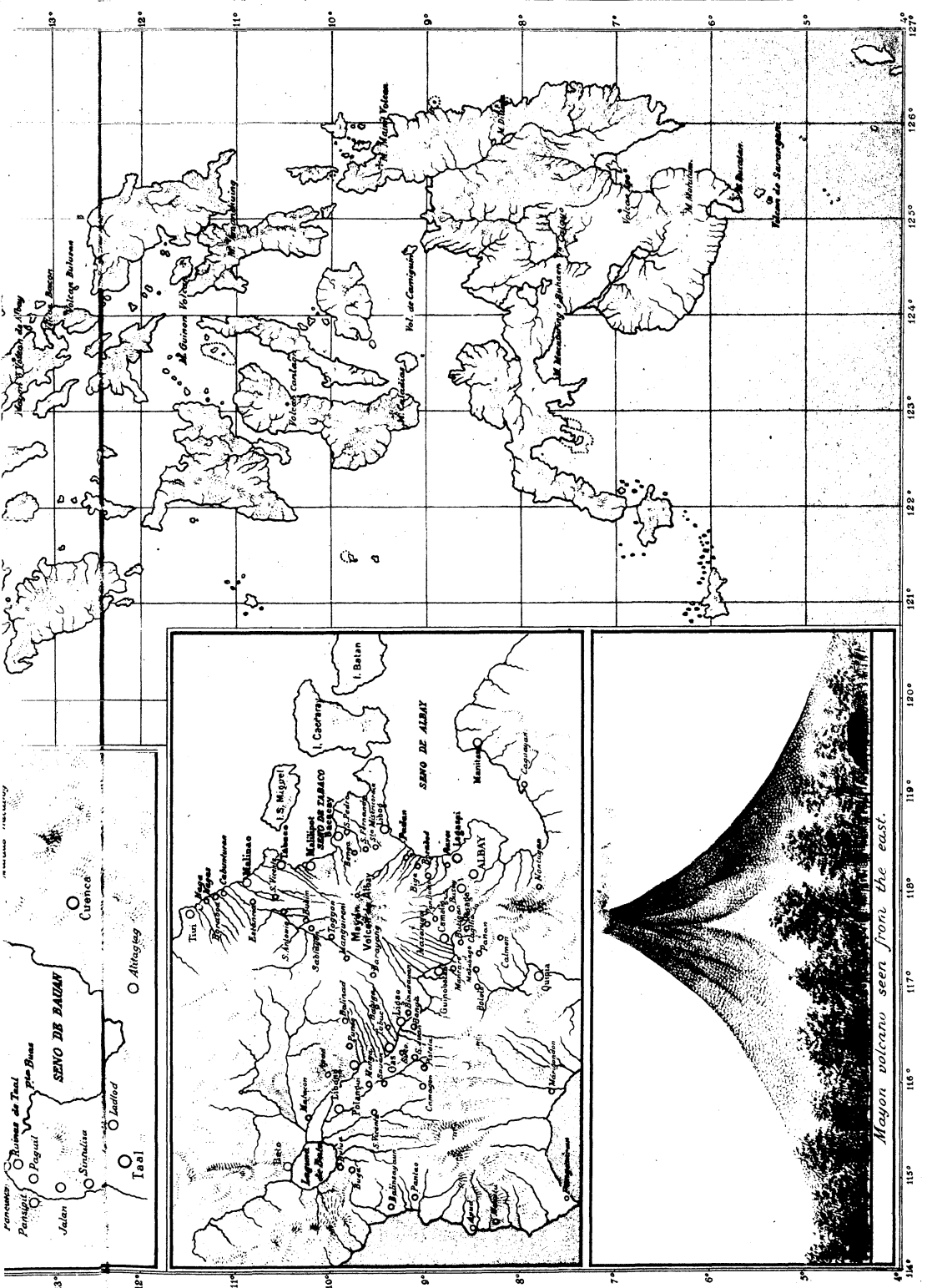
Dormant volcanoes

Approximate Scale



Taal volcano seen from the south.





Longitude E. of Greenwich.

SEISMIC AND VOLCANO-SEISMIC CENTERS OF THE ARCHIPELAGO.

INTRODUCTION.

The Philippine Archipelago comprises a very great number of islands. Omitting those of very small area, there are no less than eleven islands, each with a superficial area of more than a thousand square miles. The country is everywhere very mountainous. The chief mountain ranges run, generally speaking, along the greater axis of each island, with several arms branching therefrom.

Thus their general direction is from north to south, with more or less inclination to the east or the west, according to the general direction of the largest islands of the Archipelago. In the broad island of Mindanao there are even two eastern ranges running from north to south, the western mountains forming a group rather than a range, if we except the western range, which runs across the Dapitan district, and the farthest one running southwestward from the Silingan Mountains to Zamboanga.

There are twenty-three well-known volcanoes in the Archipelago, eleven of these being more or less active. They have been divided into several systems by some authors, but on this point there is considerable diversity of opinion.¹

The active and solfataric ones are as follows: In the Island of Luzon we have Mayon, Taal, Bulusan, and Bacon. This last lies between Mayon and Bulusan, and trustworthy persons say that at times smoke rises from it in considerable quantities. In the Babuyanes Islands we have Babuyan, Camiguin, and Didica; in the Islands of Negros, Cauaon or Malaspina; in the Island of Camiguin, just off the north coast of Mindanao, Camiguin; and in the Island of Mindanao, Apo, Macaturin, and Calayo or Volcan. The others, considered as extinct, are as follows: Caua, Arayat, Maquiling, Banajas, and Ysarof, in Luzon; Acudining in the Island of Leyte; Magars, in Negros; Dinata, Matutum, Butulan, and Sarangani, in Mindanao.

For the purposes of the new seismo-meteorological service the Archipelago is divided into four districts, or sections; this division we shall adopt in the present pamphlet, setting aside that hitherto made use of in

¹ See "Report on the Geology of the Philippine Islands," by G. I. Becker, Washington, 1901.

publications of the Observatory, especially in the last one, "El Archipiélago Filipino," in which the islands were studied seismologically from north to south.

FIRST DISTRICT.

This section is situated east of the meridian $123^{\circ} 30'$ east of Greenwich, and south of 12° north parallel, and comprises the greater part of Mindanao, the Island of Bohol, the southern part of Cebu, the Island of Leyte, and the southern part of Samar. The seismic and volcano-seismic centers of this region are as follows:

The Apo volcano-seismic center (Mindanao).—The seismic region of this focus comprises not only the southeast of the island, but also the southern part of Misamis, the whole district of Cottabato, and the sources of the Agusan River. This region contains many volcanic centers besides the Apo; the Matutum, the Butulan, and the Sarangani are three little-known volcanoes, situated in a line running south from the Apo to the Sanguir. The Apo ($7^{\circ} 3' N.$, $125^{\circ} 17' E.$, G.), the summit of which rises 10,311 feet above the level of the sea, gives evidence of its activity by numerous solfataras or jets of sulphurous vapors which escape with a sharp, shrill report and hover cloudlike over the summit of the mountain;¹ the principal solfataras break out from a ravine which starts from the main crater and runs down the side of the mountain.

The destructive earthquakes of this region have been as follows:

Year.	Month.	Day.	Hour.	Remarks.
1836	January	3		General earthquake accompanied, according to some, by volcanic eruption.
1870	November	4	3 ^h a. m.	This earthquake was felt over almost the whole Island of Mindanao. Its violence in Davao is not known; it was destructive in the northern provinces toward Misamis.
1871	June	28	3 ^h 30 ^m p. m.	Very violent earthquake.
1871	December	19	10 ^h 30 ^m p. m.	Earthquake felt in this region more than in western regions.
1872	August	24	9 ^h 1 ^m p. m.	Several shocks distinctly felt; destructive principally in the southeast of the island.
1878	September	17	0 ^h 50 ^m a. m.	Destructive effects inconsiderable.
1894	February	10	1 ^h 5 ^m a. m.	Earthquake destructive principally in the southeast of Mindanao.

Seismic center of the River Agusan.—Independent of the above-mentioned Apo center, there is probably another seismic center extending along both banks of the River Agusan about $125^{\circ} 50'$ east of Greenwich and $7^{\circ} 40'$ north latitude. This focus is possessed of great seismic activity, as is evidenced by the long series of earthquakes observed and carefully recorded by the Jesuit missionaries of that region, the observations dating from 1890.

¹See Expedición al volcan Apo por los P. P. Martin Juan y Doyle, S. J. "Cartas de Mindanao," Vol. 8, 1882, pags. 195 á 201.

The known destructive and violent earthquakes of this center are :

Year.	Month.	Day.	Hour.	Remarks.
1836	January	3		Felt in almost the whole of Mindanao Island.
1893	June	21	3 ^h p. m.	This was the beginning of a long seismic period.
1894	June	29	3 ^h 20 ^m a. m.	Less violent than those of the preceding year.
1897	April	8	9 ^h 49 ^m p. m.	Active area very small.

Volcano-seismic focus of Macaturin.—The area affected by earthquakes proceeding from this center, which is located west of the foregoing ones, is comprised within the parallels 8° 38' and 6° 8' north latitude and within the meridians 123° 38' and 124° 45' east of Greenwich. From the time of the arrival of the Spaniards in these islands in the sixteenth century only three eruptions are known to have occurred—one on the 20th of January, 1840; another on the 1st of November, 1856, while the third, according to various accounts, occurred a little before the earthquake of the 8th of December, 1871. The actual state of this volcano, situated at 7° 40' north latitude, 124° 3' east of Greenwich, is but little known. Not far distant from this and toward the east-southeast in the Misamis district, somewhere about 7° 50' north latitude and 124° 40' east of Greenwich, and very close to the Rio Grande, otherwise known as Pulangui, there is a small volcano called Calayo, or Volcan. It is in solfataric stage, the sulphurous vapors issuing not only from the crater, but also on the steep banks of the river.¹

The destructive and violent earthquakes of this region were :

Year.	Month.	Day.	Hour.	Remarks.
1636	December	21		Great landslides along the shore in Illana Bay and Polloc.
1836	January	3		It appears that this earthquake was general throughout the whole island and according to some writers was the result of volcanic eruptions in Mindanao, but it is not stated from which volcano the eruptions proceeded.
1858				Many authors say that the earthquakes of this region were the effect of an eruption of the Macaturin Volcano.
1871	December	8	5 ^h 30 ^m p. m.	This earthquake was very destructive in and around Cottabato and Polloc.
1874	August	25	6 ^h 30 ^m a. m.	Proceeded from the Zamboanga focus, where the earthquake was destructive.
1882	March			Remarkable seismic period.
1889	February	2	4 ^h 30 ^m a. m.	Caused great ruin in this region.
1893	June	3	6 ^h 37 ^m a. m.	Though violent, this earthquake was not destructive.

¹“*Cartas de Mindanao*,” Vol. 9, 1891, pags. 107 y 119. Fr. Eusebio Barrado, S. J., perhaps the first white man who traveled across the Island of Mindanao from the Misamis district to Cottabato, says: “The River Pulangui flows from Linabo through different kinds of land with a very swift current, and at a spot called Salagapon there is a wonderful waterfall. Not far from it and close to the same river is a volcano, which burst into eruption some four years ago and constantly emits vapors which burn everything about. The banks of the river are here so steep, high, and close together that they form a very narrow canyon. On the right of this bank stands an active volcano. There is no flow of lava, but it emits a column of smoke so sulphurous as to prevent any approach.”

Seismic center of Surigao.—The seismic region of this center, one of the most active in the Philippines, extends not only throughout the Peninsula of Surigao, but also to the Island of Dinagat, Siargao, and to the southern parts of Samar and Leyte. In this region no other volcanic manifestations are observable than the thermic state of the waters of Lake Mainit, situated south of Surigao $9^{\circ} 28'$ north latitude, $125^{\circ} 33'$ east of Greenwich, and also, according to Dr. Montano, some recent volcanic rocks in the neighborhood of the same lake. The theory of the author just mentioned is that Lake Mainit is the crater of some extinct volcano.

Far off to the south on the Pacific coast rises the cone Dinata, very probably an extinct volcano.

Destructive earthquakes of this region.

Year.	Month.	Day.	Hour.	Remarks.
1836	January	3		Felt almost throughout the whole island.
1871	November	5	9 ^h a. m.	The shock felt over a wide area, comprising Mindanao and eastern Bisayas, although it was destructive only in the district of Surigao.
1871	December	19	10 ^h 30 ^m p. m.	Felt along the Pacific coast of Mindanao from north to south.
1878	September	14	1 ^h p. m.	Caused great havoc throughout the country, and was the commencement of a long and very active seismic period, lasting for more than a month.
1879	July	1	2 ^h 38 ^m a. m.	
1885	February	22	3 ^h 30 ^m p. m.	This also affected all the east of Mindanao along the Pacific mountain range from Surigao to Cape San Augustine.
1889	October	6	11 ^h 06 ^m a. m.	The destructive force extended more southward than toward the north.

Volcano-seismic center of Camiguin.—This center is located on the small island of Camiguin, north of Mindanao, and opposite the coast of Misamis ($124^{\circ} 42'$ east of Greenwich and $9^{\circ} 12'$ north latitude). The existing cone was formed almost entirely during the eruption of 1871 on the side of the mountain near Catarman. This eruption was preceded by heavy earthquakes, the shocks of which were felt even in Butuan and Misamis (Mindanao), and chiefly in the direction of Bohol and Cebu. Destructive earthquakes from this center were felt from the 16th of February to the 30th of April, on which date the eruption took place. Later on both its volcanic and seismic activity gradually abated.

Island of Cebu.—On this island apparently there is no seismic center; the few earthquakes that have been felt there have radiated from seismic centers situated in other islands. The most violent were those which came from the volcano of Camiguin. An earthquake occurred on the 6th of December, 1882, causing damage to the buildings of Bantayan, a village situated in the north of Cebu. Another violent earthquake occurred on the 23d of July, 1882, at 10.55 p. m., its center being near Dapitan (Mindanao).

Islands of Samar and Leyte.—From the scant data obtained from these two islands it is difficult to ascertain whether the radiating center of the earthquakes felt there was situated within or without the islands; whether, for instance, from Mayon in the north or from Surigao in the south. There is no doubt that the Mayon earthquakes more frequently exert their influence in the direction of these islands than in that of the Camarines. A certain repetition or extension of the seismic action of the Mayon earthquakes has also been observed in the centers of Leyte and Samar, and even in Surigao. The only signs of volcanic activity found on both islands are certain solfataras or sulphuric emanations similar to those of the renowned Burauen, the geysers near Maasim, and the volcanic peaks of Amandiuing in the Sierra Dagani and Danau ranges, near Burauen, in the Island of Leyte.

Destructive earthquakes in this region.

Year.	Month.	Day.	Hour.	Remarks.
1868.	April	4		Violent in Leyte. What occurred in Samar is unknown.
1869.	August	16	3 ^b p. m.	Long seismic period commenced. The only destructive earthquake was that of the 16th of August; its greatest violence was felt in Masbate, where, in addition to the ruin caused to buildings, the earth was rent with long, deep crevices, and even small islands are recorded to have disappeared in the region north of Ticao. Information is lacking from Albay, where the shock was probably still more violently experienced.
1870.	March	2	3 ^b a. m.	Not destructive; and felt more in Samar than in Leyte.
1873.	March	19	1 ^b p. m.	Area of action small, and the only damage caused thereby was in the pueblo of Mercedes (Samar).
1877.	July	23	4 ^b 24 ^m p. m.	Violent; especially so in Leyte.
1890.	February	7	0 ^b 40 ^m a. m.	More violent in the north of Samar than in the Island of Leyte.
1897.	October	19	8 ^b 05 ^m a. m.	Destructive in the northeast of Samar.

SECOND DISTRICT.

This district lies south of the twelfth parallel and west of the meridian 123° 30' east of Greenwich, and comprises the western portion of Mindanao and the Islands of Negros and Panay. There are few important seismic foci in this district.

Seismic center of Zamboanga.—The seismic area of this center comprises the western part of the peninsula formed by the narrow neck of land between Pangil and Yllana Bays. The Zamboanga earthquakes rarely extend their influence beyond this peninsula, owing partly to the configuration of the land and perhaps more especially to the distance of one of the centers, which is situated probably in the sea north of the Joló Archipelago, where a submarine volcano is said to exist.¹

¹See "La actividad sísmica en el Archipiélago Filipino durante el año 1897," by Fr. J. Coronas, S. J.

The destructive and violent earthquakes of this center have been :

Year.	Month.	Day.	Hour.	Remarks.
1871	November	29	4 ^h 30 ^m p. m.	Caused slight damage to buildings.
1874	August	25	6 ^h 30 ^m a. m.	Damaged buildings, and the ground was cracked on all sides.
1885	July	23	10 ^h 45 ^m a. m.	Very violent.
1889	February	2	4 ^h 30 ^m a. m.	Apparently radiated from a submarine center toward the east.
1897	September	21	1 ^h 17 ^m p. m.	This earthquake was a very remarkable one. ¹

¹ "La actividad sísmica en el Archipiélago Filipino durante el año 1897," by Fr. Coronas, S. J.

Seismic center of Dapitan (Mindanao).—The northwestern part of Mindanao seems to be affected neither by the shocks proceeding from the Zamboanga center nor by those from that of Macaturin. They may be attributed to some other center situated toward the west of the Bahía Yllana, from which place various shocks experienced in Zamboanga and Cottabato appear to radiate. Only one destructive earthquake has been felt, and that on the 23d of July, 1885, at 10.46 p. m. Its force was exerted not only over the whole Island of Mindanao, but even as far as the Bisayas. At Dapitan and the neighboring villages its destructive effects were not very great.

Islands of Panay and Negros.—Owing to the scarcity of records of earthquakes felt in the Island of Negros, it is quite impossible to know whether or not the center radiating toward Panay is situated in Negros, for here, besides a number of extinct cones, we find the Volcano Canloan, or Malaspina (10° 25' north latitude, 123° 6' east of Greenwich). The Official Guide of Manila for the years 1893 to 1896 and 1897 counts this volcano among the active ones of the Archipelago. An eruption is said by some authors to have taken place in 1866 and another, although a slight one, in the year 1894. There is no doubt that many shocks felt in Panay and Negros proceed from the Albay and Taal centers.

Destructive or violent earthquakes felt in Panay and Negros Islands were as follows :

Year.	Month.	Day.	Hour.	Remarks.
1778	May	13	6 ^h a. m.	Many churches and other buildings of stone thrown down, with great loss of life resulting therefrom.
1881	July	11	0 ^h 35 ^m p. m.	Damage to buildings but slight.
1887	February	2	11 ^h 0 ^m p. m.	Great damage to buildings throughout all Panay; no report could be obtained from Negros.
1890	September	23	6 ^h 15 ^m p. m.	Violent in Negros only.

THIRD DISTRICT.

This district extends northward from parallel 12° north latitude and eastward from the meridian 122° east of Greenwich, comprising the southeastern parts of Luzon, Camarines, Albay and Sorsogon, Catanduanes, Ficas, Masbate, and Burias Islands and the northern part of Samar. In this district are situated almost all the most important and

most numerous seismic centers of the Archipelago. However, we shall restrict ourselves to giving some facts relating to the Volcano Mayon.

Volcano-seismic center of Mayon.—Mayon, or the volcano of Albay, the most famous Philippine volcano and perhaps the most beautiful volcanic cone in the world, rises in the northern part of the Albay district near the Bays of Legaspi and Tabaco, at $13^{\circ} 16' 30''$ north latitude and $123^{\circ} 40' 54''$ east of Greenwich. Its height, according to the latest measurements, is 8,970 feet, and it is visible at a great distance. Its activity appears to be between the first and second period, according to Stohr's hypothesis, for the ashes thrown out during its eruption are frequently interrupted or accompanied by flows of lava. Some of these eruptions have been very serious,¹ and the rumbling sounds and the shocks have been very strong and frequent.

Secondary centers of this district.—The volcano of Bulusan at Sorogon ($12^{\circ} 47'$ north latitude, $124^{\circ} 1'$ east of Greenwich), which burst out in eruption in 1852, and still retains many traces of solfataric action, at times emits an abundance of aqueous vapor and sulphurous fumes. The Bacon, situated between the Albay and Bulisan volcanoes, is similar to the last one. Malinas, in the Province of Albay, is another center where the most remarkable solfataras and hot springs in Luzon are to be found; some of the springs here deposit siliceous sinter in various fantastic forms, and pyritous deposits of recent date are also found.

Destructive or violent earthquakes of this district, with or without eruption.

Year.	Month.	Day.	Hour.	Remarks.
1628				The precise date of the occurrence of this earthquake is unknown; it was destructive chiefly in Camarines.
1766	July	20		Eruption accompanied by violent shocks during several months.
1811	October	5		Long seismic period; the shocks felt on the 5th of October damaged many churches and other buildings in Albay and Camarines.
1855	March	22		Small eruption accompanied by a violent earthquake felt with force throughout Luzon.
1875	May	19	11 ^h 30 ^m a. m.	Felt more strongly in Camarines than in Albay.
1877	July	5	0 ^h 7 ^m p. m.	Very violent in Albay and in the islands of Masbate and Ticao.
1897	May	13	7 ^h 44 ^m p. m.	Destructive in the Island of Masbate and in some villages in the Province of Albay.

Eruptions of the Mayon Volcano.

1616				The most ancient reported eruption, but without precise date or any remark.
1766	July	20		It lasted 6 days, during which, an immense column of ashes and smoke rose in the air and a stream of lava poured down the east side of the volcano. It is reported that some months after this eruption, in October, the heavy rainfall accompanying a violent typhoon carried down desintegrated fragmental ejecta, burying plantations and whole villages. A similar fact is reported to have occurred in October of 1825, which destroyed the lives of about 1,500 human victims.

¹See "La erupción del volcan Mayon en 1897," Manila, by Fr. J. Coronas, S. J.

Eruptions of the Mayon Volcano—Continued.

Year.	Month.	Day.	Hour.	Remarks.
1800.				Many but not very destructive eruptions.
1814.	February	1		Dreadful eruption, which well-nigh buried under its streams of lava and ashes the whole country around the pueblos of Budias, Camalig, and partially destroyed Guinobatan and Albay. About 1,200 lives were lost. The ashes were carried through the air as far as the coast of China and the darkness produced by the clouds of ashes extended even over North Luzon. Since the year 1814 many slight eruptions occurred, such as those of July, 1827; May, 1835; January, 1845.
1853.	July	13		Eruptions of very short duration. During 3 or 4 hours the crater belched forth smoke, ashes, and heavy stones, which latter rolling down the steep slopes of the mountain side demolished many houses and killed 35 persons.
1855.	March			Not violent.
1858.				Lava flowed quietly from the summit during the greater part of this year.
1868.	December	17		Small eruptions.
1871.	December	8		Moderate eruption; some lava streams flowed eastward.
1872.	September			This one lasted 4 days, accompanied by strong, rumbling sounds. No loss of life or property.
1873.	June	20		Longer than the preceding one, but with the same peaceful characters.
1881.	July	6		Very long, but weak; it began on the 6th of June, ending in August of 1882. The lava flowed from many crevices near the summit and was accompanied by rumbling sounds.
1885.	November	21		Flows of lava on the south, southeast, and southwest sides of the volcano.
1886.	July	8		Long eruptive period; lava flowed quietly excepting on the 8th of July of 1886, and the 22d and 27th of February, and the 1st and 9th of March of 1887, when the manifestations increased, the crater hurling forth ashes, stones, and igneous vapors, with an accompaniment of rumbling sounds.
1888.	December	15		Small and short eruption.
1890.	September	10, 30		Do.
1891.	October	3		Do.
1892.	February	20		A very noisy eruption, but not destructive; the flows of lava were very abundant and the summit of the crater was greatly deformed, the thin edges of which completely disappeared.
1893.	October	4		Similar to the preceding one.
1895.	July	20		Very weak.
1896.	August	31		Do.
1897.	June	25		Very strong eruption, lasting 24 hours. Great loss of life (350 victims) and property. ¹
1900.	March	1		Strong eruption, lasting 4 days.

¹ See "La Erupción del Volcan Mayon en 1897," Manila, 1898, by R. Fr. F. Coronas, S. J.

FOURTH DISTRICT.

This district extends from parallel 12° north latitude northward and from meridian 122° east of Greenwich, comprising the whole of the main part of Luzon and the Island of Mindoro. In this district lie the active volcanoes Taal and Banajao and the extinct ones Maquiling and Arayat.

Volcano-seismic center of Taal.—The Taal volcano (14° 2' north latitude, 120° 57' east of Greenwich.) is a very remarkable one and is readily accessible from Manila; it lies in the middle of the Lake of Bombon. One comparatively large crater and several other small extinct ones near by form an island called Pulo Volcan, which has an area of some 220 square miles.

The form of the central or main crater is approximately oval, with its major axis 7,546 feet long and the minor axis 6,233 feet. The interior surface is that of an inverted cone whose height is approximately that of the edge of the crater above the water of the lake. At the bottom of the crater are to be found several small cones, only one of which is active and emits great quantities of vapor. There are also three boiling lakes, containing metallic oxides and salts in solution, which give to the waters of the smaller lake a pure emerald green color and to the larger one a reddish-yellow tint. In the smaller lake every few minutes the water in the center is blown up like an immense bubble, which, rising above the surface, finally bursts, revealing a black orifice and causing the boiling and very turbulent water to assume all imaginable colors. The quantity of aqueous and sulphurous vapor escaping from the lakes, from the active cone, and from the open crevices on all sides, is sufficient to form a broad, smokelike column of vapor which is visible especially during the night and in the early morning. At some distance and before reaching the edge of the crater, where a view of the bottom can be obtained, the rumbling sound produced by the escaping vapor, under the influence of the mysterious subterranean forces, can be heard like that of an immense boiling kettle.

It is impossible for us to describe the beauties of the crater itself, whose bottom and interior walls, accessible at various points, present such varied structures and colors, from the black and compact basalts to the fragile, spongy, and almost transparent recent scorial. The most finished description would be powerless to give even an approximate idea of that grand amphitheater, where every stone has its history, having been thousands of times cast up to great heights and again dissolved and deposited, until finally nothing remains but a mass of transparent and colored crystals.¹

Not far from the Taal Volcano to the northeast rises that of Maquiling, at the northwest base of which, close to the shore of the Laguna de Bay, are situated the well-known hot springs named Los Baños. To the south also many boiling springs are to be found. History records no eruption of this volcano. Almost east from Taal, towering over Laguna de Bay, can be seen, even from Manila Bay, the magnificent cone of Banajao, 7,382 feet in height. According to the "Estado geográfico," it suffered a violent eruption in 1730 and has since then been dormant. Northward from Manila there is the striking conical Arayat, looming up over the extensive plain between Nueva Ecija and Pampanga. We omit many other peaks known to be volcanic, rising here and there along the western coast.

It is an undoubted fact that the greater number of the most violent shocks experienced in Manila radiate from the Taal center. The fact

¹See "El volcan de Taal," by D. J. Centeno.

observed in the case of many violent earthquakes, that their epicentric area seems to proceed now northeastward, now northward, from the volcano, may indicate that the Volcanoes Taal, Maquiling, and Banajao belong to a single volcanic system. The seismic waves coming from this center travel more easily northward along the western ranges of mountains, the Sierra of Mariveles and Zambales, the central hills of Morong, throughout the great area of tuff, stretching to Bulacan, and even southward to the Island of Mindoro, than along the mountains of Camarines.

Destructive or violent earthquakes of this region.

Year.	Month.	Day.	Hour.	Remarks.
1599	June			Took place after a long dry period.
1600	January	2	12 ^h a. m.	Its duration of 7 minutes was very extraordinary; many buildings fell and many people were injured.
1610	November	30		Very violent; shocks appeared to proceed from east-southeast.
1645	December	1	8 ^h p. m.	Almost the whole city was laid in ruins; destruction to property was immense and much loss of life.
1646	March			Long series of shocks lasting for 60 days many of these shocks were violent.
1658	August	20	5 ^h p. m.	Very violent but of short duration; destroyed buildings which the earthquake of 1645 had left.
1665	June	19		Reports of this earthquake are very few; many buildings were ruined and 19 people killed.
1675	January or February.			Destructive in the neighborhood of the Taal Volcano and in the Island of Mindoro where many fissures were opened in the ground and many landslides occurred.
1683	August	24		Damaged some buildings.
1699				The exact date of this earthquake is unknown. It is reported by Mr. Perey, who quotes Mr. Le Gentil.
1716	September	24		Accompanied an eruption of Taal Volcano.
1728	November	28		Caused great loss of property in Manila.
1749	August	12	9 ^h a. m.	Accompanied eruption of Taal.
1754	May			Long period of violent shocks felt in the southern provinces of Luzon during an eruptive period of Taal Volcano.
1767	November	13	3 ^h 25 ^m p. m.	Caused cracks in stone walls and the falling of tiles.
1771	February	1		Threw down the church of Ermita.
1796				Many chroniclers report during this year a great number of violent shocks felt in Manila, but the exact date of these earthquakes is unknown.
1797	February or March.			Caused but slight damage to buildings.
1824	October	16		Damaged many buildings in Manila and in the provinces of the south.
1852	September	16	6 ^h 45 ^m p. m.	The center of this destructive earthquake appears to have been in the Taal Volcano. Many fissures were opened in the earth around about the volcano. Damages to buildings were very great in the provinces of Manila, Cavite, Bulacan, Laguna, Tayabas, and in the Island of Mindoro. The hill Ubamba near Subic (Zambales) was reported to have been almost leveled to the ground.
1852	December	24		Was destructive only in the vicinity of Taal.
1855	March	22		Accompanied an eruption of the Volcano Mayon in Albay.
1862	do	4	5 ^h 30 ^m p. m.	The damage caused was very slight.
1862	July	{ 13 16	{ 4 ^h 25 ^m p. m. 7 ^h 30 ^m p. m.	{ These two earthquakes were destructive only in the district of Principe and along the eastern coast of Luzon.
1863	June	3	3 ^h 20 ^m p. m.	Threw down Manila Cathedral, and in the town and neighborhood destroyed 25 public and 570 private buildings. Many people were buried in the ruins of the Cathedral. The destructive force was felt chiefly in the southern and eastern provinces.
1869	October	1	11 ^h 35 ^m a. m.	Exercised its most destructive force in the Province of Batangas around the Volcano of Taal. Violent only northward; strong in the Island of Mindoro.

Destructive or violent earthquakes of this region—Continued.

Year.	Month.	Day.	Hour.	Remarks.
1872	December	29	11 ^b 48 ^m a. m.	Its epicentric area ran from Taal Volcano to Zambales.
1873	November	14	5 ^b 30 ^m p. m.	Most violently felt from Taal Volcano eastward and southward in the Island of Mindoro and in the Province of Tayabas and Laguna.
1875	May	19	11 ^b 30 ^m a. m.	Destructive in the Provinces of Tayabas and Camarines.
1877	June	24	5 ^b a. m.	Felt violently about the Taal Volcano.
1880	July	18	0 ^b 40 ^m p. m.	The last destructive earthquake felt in Manila; it laid in ruins the town and the neighboring provinces.
1889	May	29	2 ^b 23 ^m a. m.	Its destructive force restricted to the vicinity of Taal Volcano.

Eruptions of the Taal volcano.

1709				Eruption without loss of life or property.
1716	September	24		Violent eruption accompanied by strong earthquakes, which shook the neighboring regions.
1749	August	12	9 ^b a. m.	Two violent eruptions, the first on the evening of the 11th, the second at 9 a. m. on the 12th, the latter accompanied by a violent earthquake. Numerous witnesses report that many explosions took place in a line running from Taal to the Maquiling Cone on the banks of the Laguna de Bay.
1754	May	15	9 ^b p. m.	The greatest eruption reported of this volcano; it continued with intervals till December 1. Four villages lying round about the lake were completely destroyed. No great eruption has occurred since 1754. In 1808 and in 1873 there were outbreaks, but the damage done seems to have been confined to the island itself.
1874	May	17		Eruption of black smoke and ashes.
1874	July	19		Eruption of gases, which were so sulphurous that the characteristic odor was perceptible as far as the town of Talisay. A large herd of cattle died on the island of Pulo Volcan on whose western shore the abundant vegetation was almost completely burned up.
1878	November	12		From the end of October until the 12th of November subterranean noises were heard frequently in the direction of the volcano. On the day mentioned the eruption began and lasted until the 15th, covering the whole island of Pulo Volcan with a light layer of volcanic ashes.
1880	June	8		From the 8th of June the volcano was observed to be more active than usual, and sometimes at night the crater was covered with a glare. On the 17th, 18th, 19th, 20th and 21st of July subterranean noises were heard, and many witnesses at Talisay, some 6 miles distant, report that from time to time a small ball of fire (apparently about two and a half feet in diameter) appeared above the crater. These balls, after reaching a considerable height, burst into small fragments, some of which fell back into the crater and the remainder upon the exterior slope.

Seismic centers of Pangasinan and Nueva Vizcaya.—It is not easy to determine whether or not the seismic center disturbing the Provinces of Pangasinan and Nueva Vizcaya form but one center or system situated toward the connecting point of the two ranges of mountains, namely, the central and the eastern one, called the South Caraballo. The volcanic vents and the many fissures found in the Benguet district show that there once existed at this place a very important volcanic center,¹ the

¹See "Terremotos de Luzon, 1892," by Sr. E. Abella y Casariego.

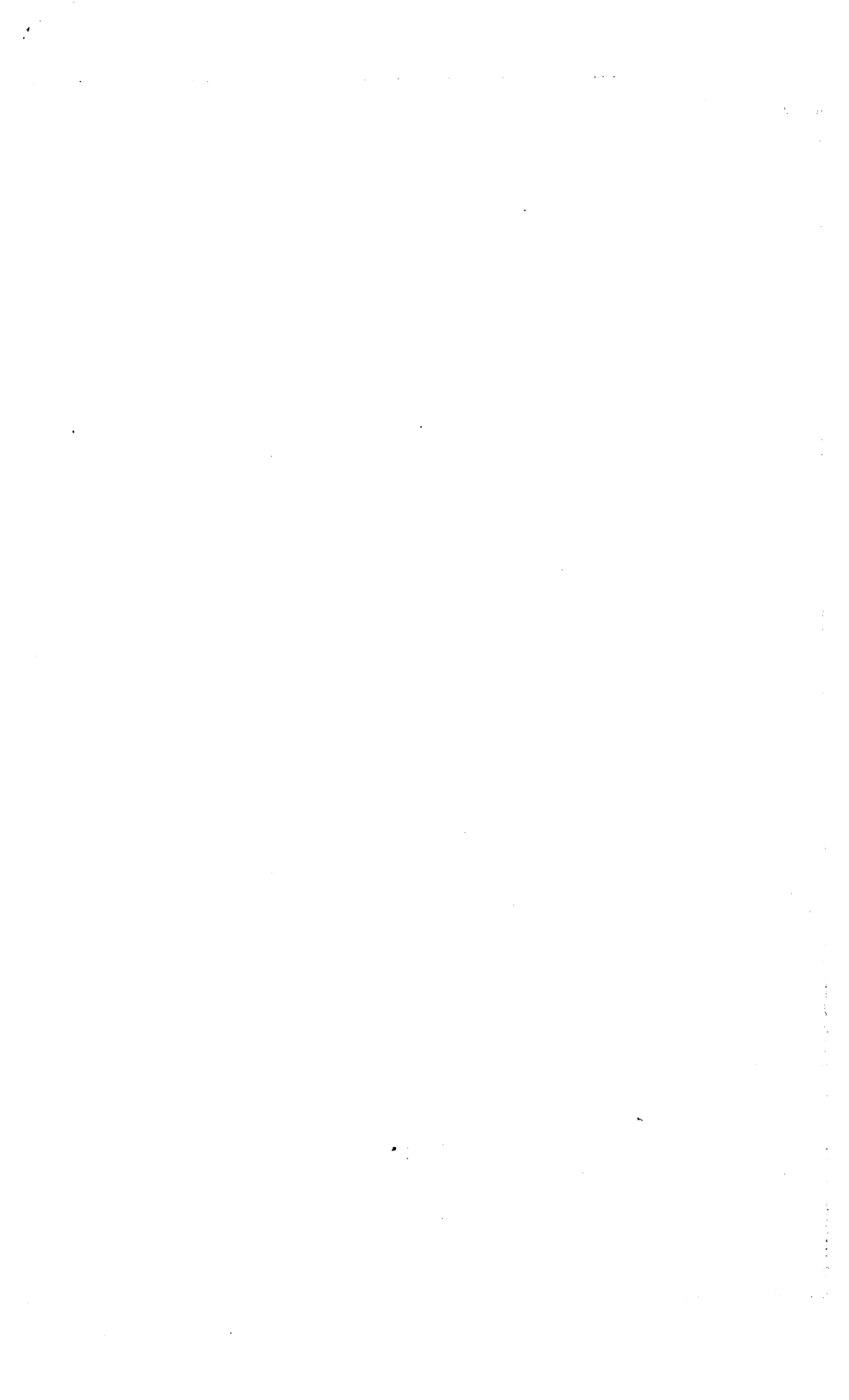
relics of whose activity are still to be found in the form of various hot, sulphurous springs. Thus the true center, radiating sometimes south-westward and at others northeastward, seems to be situated near this district, although the shocks are more frequently felt with force in the alluvial plains of Pangasinan and Nueva Vizcaya than in the highlands of Benguet. Nevertheless the characteristic circular form of the plain in which La Trinidad is situated has led the inhabitants to refer its formation to some recent seismic event. The story seems to be founded on an old chronicle of the Order of the Agustines, according to which at the beginning of the eighteenth century quite a large number of cottages situated east of Aringay and occupied by the natives disappeared during a great earthquake which caused the submersion of an extensive tract of land.

It has even often been observed that the manifestations of this same center were felt more strongly in a northeasterly direction than in a southwesterly one, as if there were two independent centers. The seismic waves radiating from this center ordinarily extend into the Provinces of La Union, Pangasinan, Nueva Ecija, Nueva Vizcaya, and Benguet.

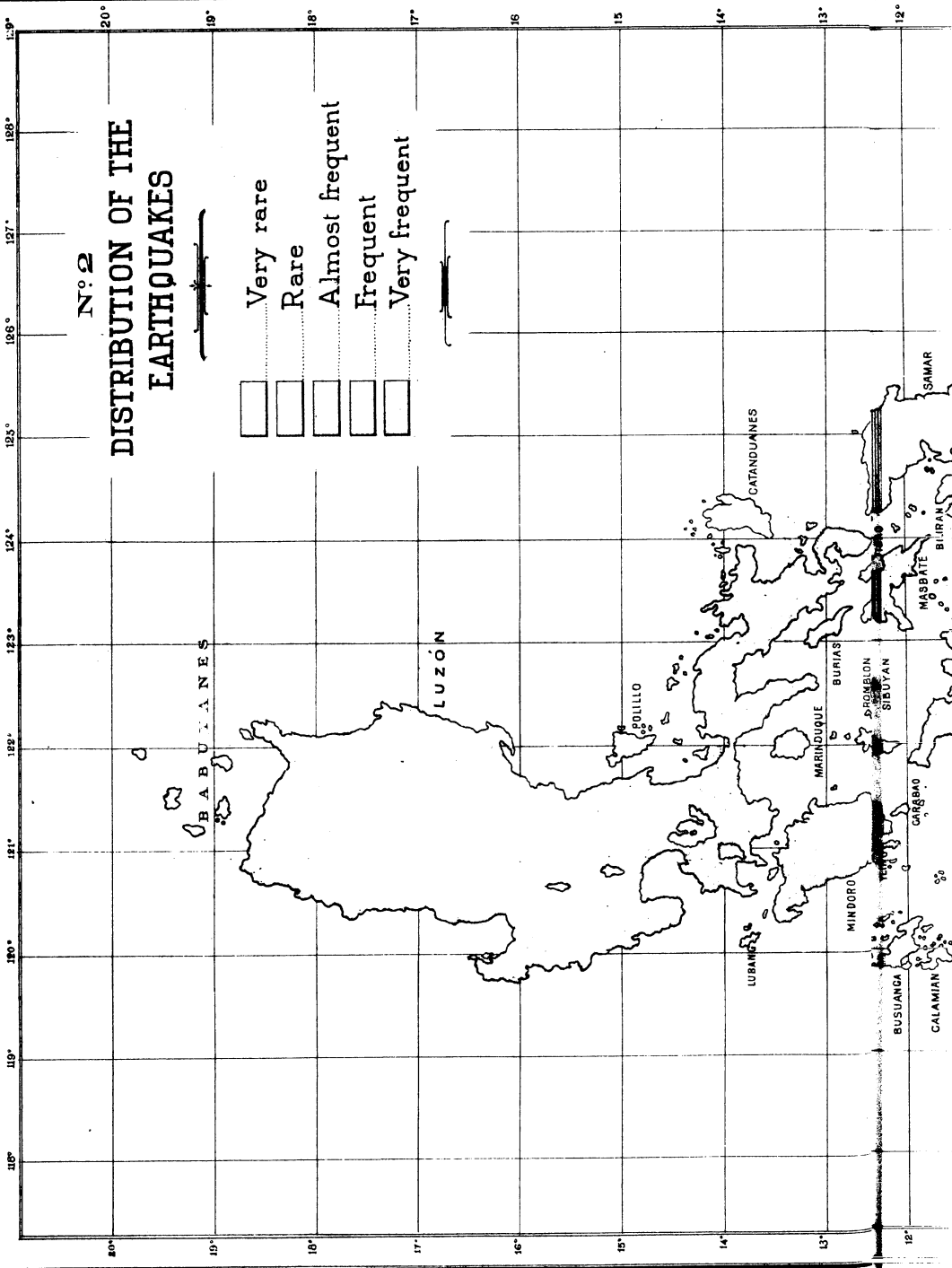
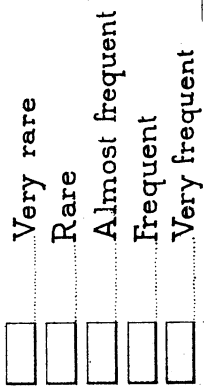
Destructive and violent earthquakes of this center.

Year.	Month.	Day.	Hour.	Remarks.
1627	August			Chronicles report large landslides on the Caraballo peaks.
1645	December	1	8 ^h p. m.	This is the earthquake which laid Manila in ruins; it was also destructive in the northern provinces.
1728	November	28		Was destructive in the whole Fourth District.
1881	January	3	8 ^h 30 ^m a. m.	On this date there commenced in Nueva Vizcaya one of the longest and most dreadful seismic periods on record; during the months of January, May, July, August, and September, the shocks were almost continuous. The seismic center was probably near Dupax. The strongest seismic waves extended over all the provinces of Luzon.
1892	March	16	9 ^h 1 ^m 52 ^s p. m.	Spread ruin throughout almost the whole Province of Pangasinan, not a single stone building escaping without serious damages.

Seismic center of the north of Luzon.—In this northern region there probably exist two seismic centers, one to the east and the other situated to the west of the central range of mountains. In fact, many earthquakes felt with great force in North and South Ilocos and Abra are almost imperceptible in the eastern provinces of Cagayan and La Isabela. On the other hand, many others have been known to be very powerful in the latter provinces throughout the Cagayan Valley and very feeble in the former. This tends to show that the two centers are almost independent. Nevertheless, they very probably belong to one general seismic system, like the one in Nueva Vizcaya and Pangasinan. Neither in the eastern nor in the western region are there well-known important volcanic centers. The old chronicles report an eruption which



N° 2 DISTRIBUTION OF THE EARTHQUAKES



BABUYANES

LUZÓN

LUBANG

MINDORO

BUSUANGA

CALAMIAN

BOLILLO

MARINDUQUE

BURIAS

DABOBLON

SIBUYAN

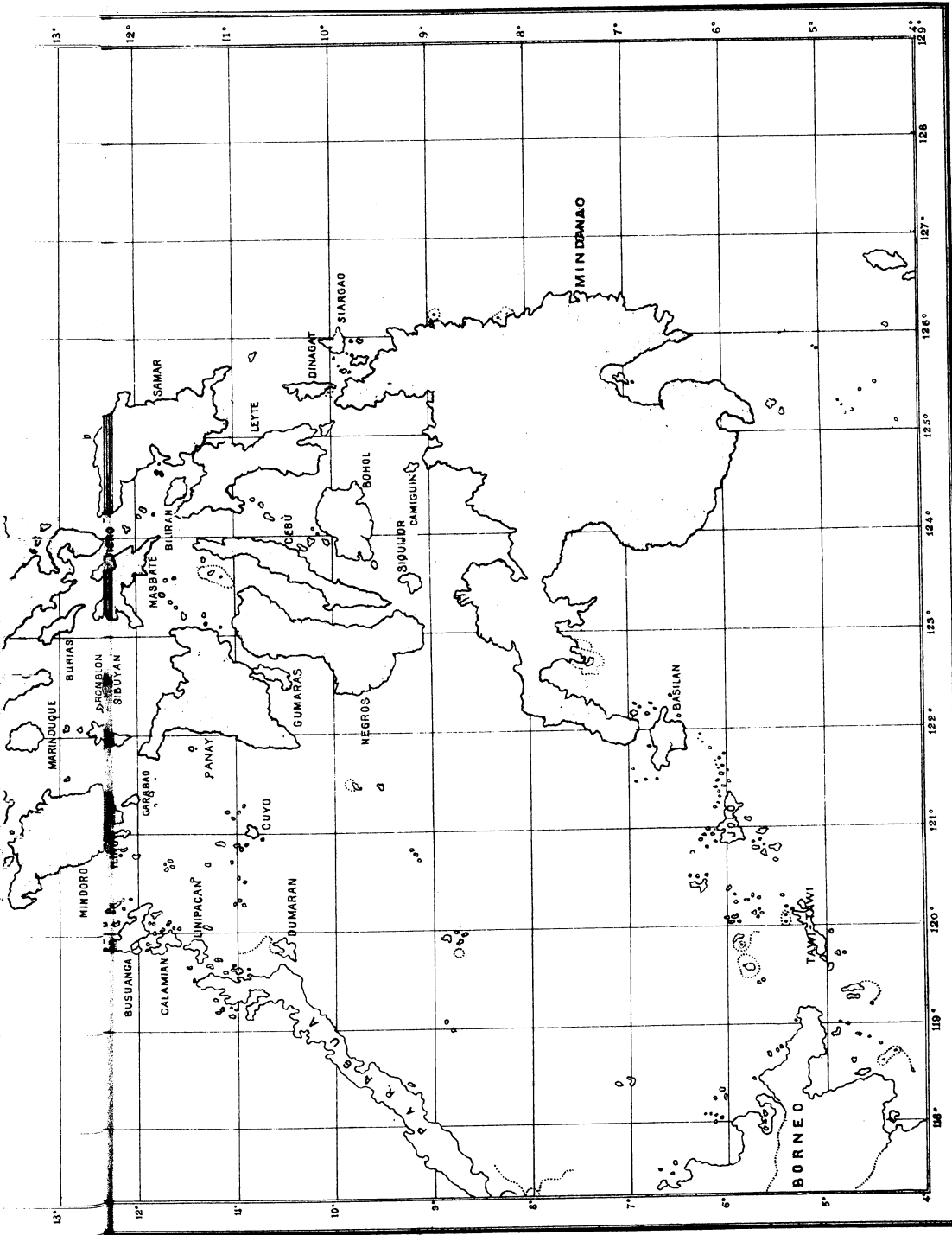
CARGASAO

CATANDUANES

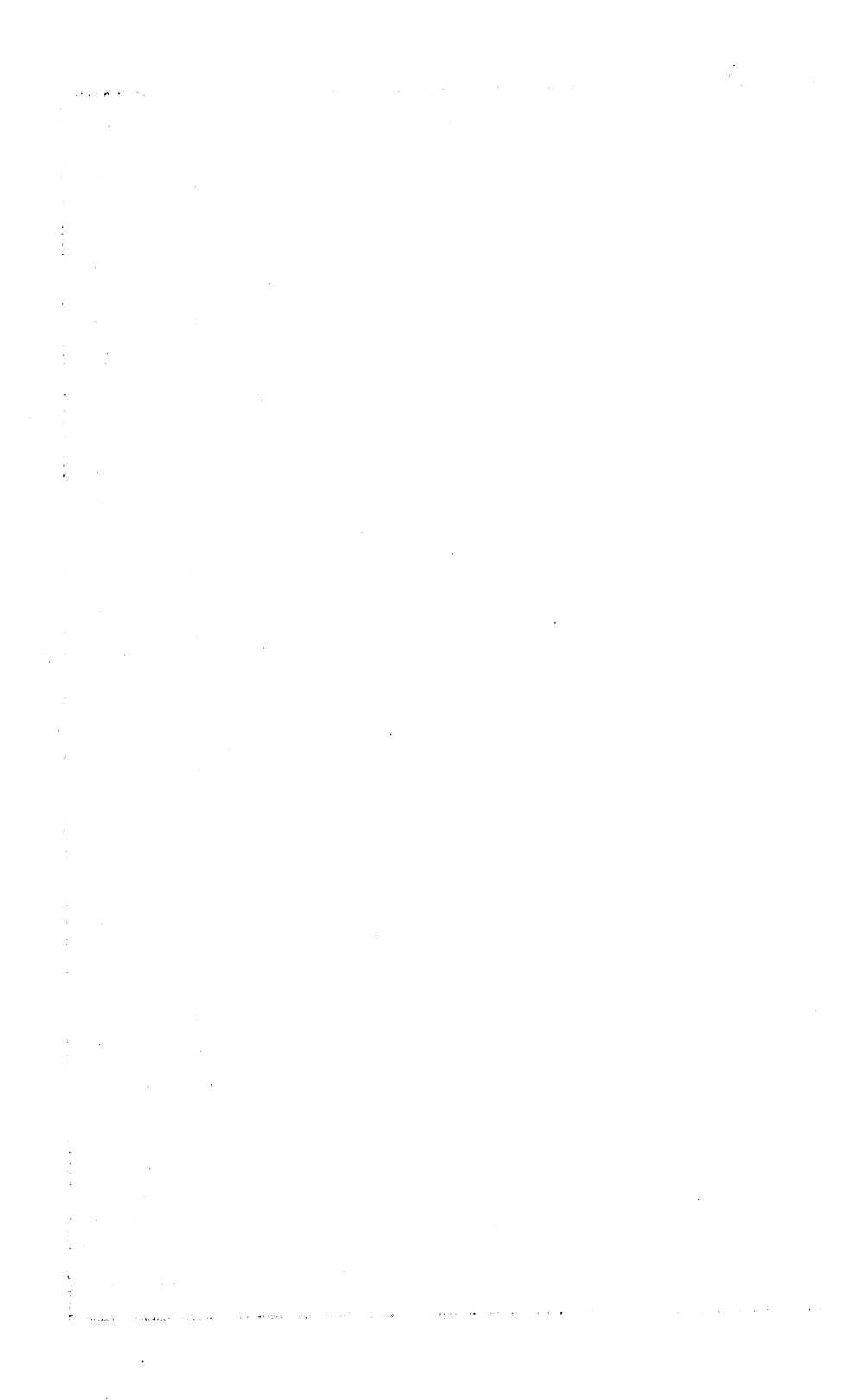
MASBATE

BIURAN

SAMAR



Longitude E. of Greenwich.



took place east of Ilocos Norte, near the Caraballos Norte, coinciding with another in the Sanguir Volcano. The reports are not accurate enough to locate the place. In the eastern provinces not far from Cape Engaño there is a volcanic cone known as Caua ($18^{\circ} 13'$ north latitude, $122^{\circ} 4'$ east of Greenwich), which is now in the sulfataric stage and which was seen smoking in the year 1860; it is commonly known among the natives as a "fire mountain."

Besides these centers of Luzon there are two active volcanoes, one in the Island of Babuyan Claro ($19^{\circ} 40'$ north latitude, $121^{\circ} 56'$ east of Greenwich) and the other in the Didica Reefs ($19^{\circ} 2'$ north latitude, $122^{\circ} 9'$ east of Greenwich). They are known as "smoking mountains." The well-known volcano of Camiguin ($18^{\circ} 55'$ north latitude, $121^{\circ} 52'$ east of Greenwich) is now in the sulfataric stage.

Destructive and violent earthquakes of the northern region.

Year.	Month.	Day.	Hour.	Remarks.
1627	August			Chroniclers exaggerate the extensive landslides which occurred on the Caraballo peaks. The shocks were very violently felt in all the northern provinces.
1641	January			Eruption at Ilocos; its location almost unknown. The Sanguir Volcano suffered an eruption at almost the same time, and according to many ancient reports another took place in the Jolo Island.
1645	December	1	8 ^h p. m.	This earthquake was very destructive in Manila. It was felt with great force in the north; at Lallo large fissures were opened in the earth and many large landslides occurred on the hills.
1728	November	28		Very destructive in the whole Fourth District.
1862	September	9	3 ^h a. m.	
1866	December	29	3 ^h a. m.	Destructive chiefly in Ilocos Norte.
1870	May	23	11 ^h 55 ^m p. m.	
1874	August	3		It was destructive only in the Lepanto district. Felt more violently in the northern than in the northeastern provinces.
1879	October	14	9 ^h p. m.	
1879	December	19		This earthquake was destructive only at the northwestern edge of Luzon.
1896	September	13	1 ^h 02 ^m p. m.	
1897	August	15	8 ^h 22 ^m p. m.	Destructive chiefly at Abra and Ilocos Sur.

RELATIVE FREQUENCY OF EARTHQUAKES IN THE ARCHIPELAGO.

Map No. 2 shows the relative activity of the different centers, or the relative frequency with which the earthquakes have been felt in every region of the Archipelago. This plate is chiefly based on the lists gathered during the last eighteen years which immediately preceded the war. This is the most complete record at our disposal. The scarcity of data from some provinces has obliged us in some cases to calculate the frequency of the shocks by that of the neighboring provinces, and thus the value of the result is but approximate. The regions referred to are the central districts of Luzon, inhabited by savages, and the Islands of Mindoro, Negros, Cebú, Samar, and Leyte. The reports received from these islands came generally from only one place in each island, namely,

the chief town. The values found for Manila are relatively too great, even if we take account of the very perceptible earthquakes alone; and the reason for this is too clear to need explanation. The more active centers are those of Surigao, Albay or Mayon, and Taal. But neither in these nor in other centers is the intensity of the shocks proportional to the frequency of the earthquakes, as is shown in the foregoing chapters.

The mean frequency of earthquakes in the whole Archipelago in the last eighteen years is given in the following table (I) in which the unit taken is the earthquake day as it is considered by many seismologists, omitting the aftershocks, which are sometimes very numerous during the day of the earthquake itself, and often for many consecutive days.

TABLE I.

Year.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total.	Means.
1880..	1	4	2	4	0	2	7	13	8	5	6	4	56	4.7
1881..	7	8	8	6	7	4	6	7	13	6	2	6	80	6.7
1882..	4	4	4	2	5	7	6	2	9	4	5	3	55	4.6
1883..	1	6	4	3	1	2	3	4	3	3	1	1	32	2.7
1884..	4	3	4	1	3	5	2	4	4	2	2	7	41	3.4
1885..	1	5	3	3	4	1	7	3	3	9	8	3	50	4.2
1886..	5	2	2	2	5	3	1	2	1	2	3	1	29	2.4
1887..	1	5	6	8	2	3	2	2	4	5	3	2	43	3.6
1888..	4	3	2	1	7	2	2	3	3	6	2	6	41	3.4
1889..	6	3	1	5	5	2	2	3	4	1	3	3	38	3.2
1890..	3	3	2	3	5	4	6	1	1	3	0	4	35	2.9
1891..	3	1	4	3	4	6	3	7	8	3	5	4	51	4.3
1892..	5	7	4	6	4	3	6	4	8	3	3	3	56	4.7
1893..	5	3	3	5	4	10	5	6	5	2	7	5	60	5.0
1894..	4	8	2	9	1	6	8	5	7	4	2	4	60	5.0
1895..	7	7	0	2	7	3	7	6	6	4	9	4	62	5.2
1896..	7	6	7	3	8	5	8	10	4	3	3	2	66	5.5
1897..	10	9	9	9	10	9	7	8	7	7	15	7	107	8.9
Total	78	87	67	75	82	77	88	90	98	72	79	69	962	80.4
Mean	4.3	4.8	3.7	4.2	4.6	4.3	4.9	5.0	5.4	4.0	4.4	3.8	53.4	4.5

From this table we find an average of 53.4 earthquake days for the year, or 4.5 per month, no small number indeed when we remember that the unit is the earthquake day and that it does not include the subsequent shocks. The same table also shows a maximum frequency in 1881 and 1897, and a minimum in 1886. Since the year 1893 the numbers show an increase, probably due to the fact that during this period there have been more private observers of such phenomena throughout the islands. Hence we may reasonably expect that when our new meteorological service shall have been established and is in working order, the table of the frequency of earthquakes will show a still further increase over that previously given, based on somewhat deficient data.

If, following the method of Mr. Montessus de Ballore, applied by him not only to many European regions, but also to our Archipelago, we study the earthquake frequency itself, taking the above period of eighteen years, we shall find the following numbers for the principal provinces of the Archipelago.

Fig. 1. Monthly Distribution of 962 earthquakes

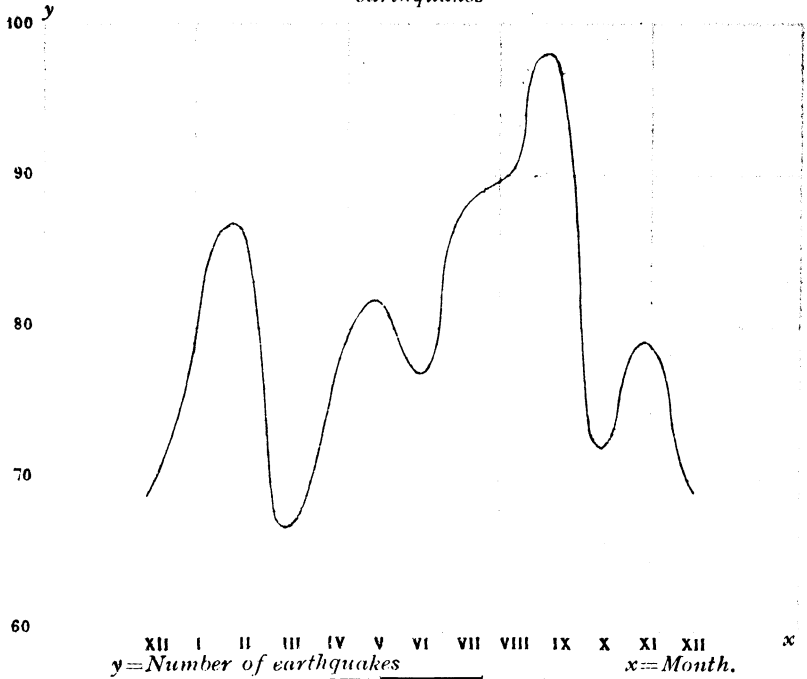


Fig. 2. Seismic activity Between 1880 and 1897

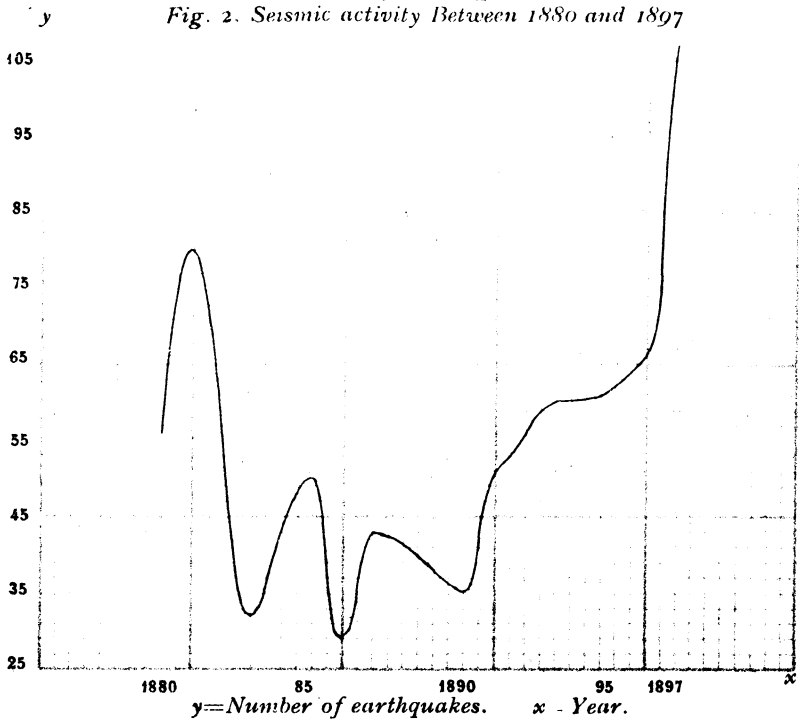


Fig. 1. Seasonal Distribution of 962 earthquakes

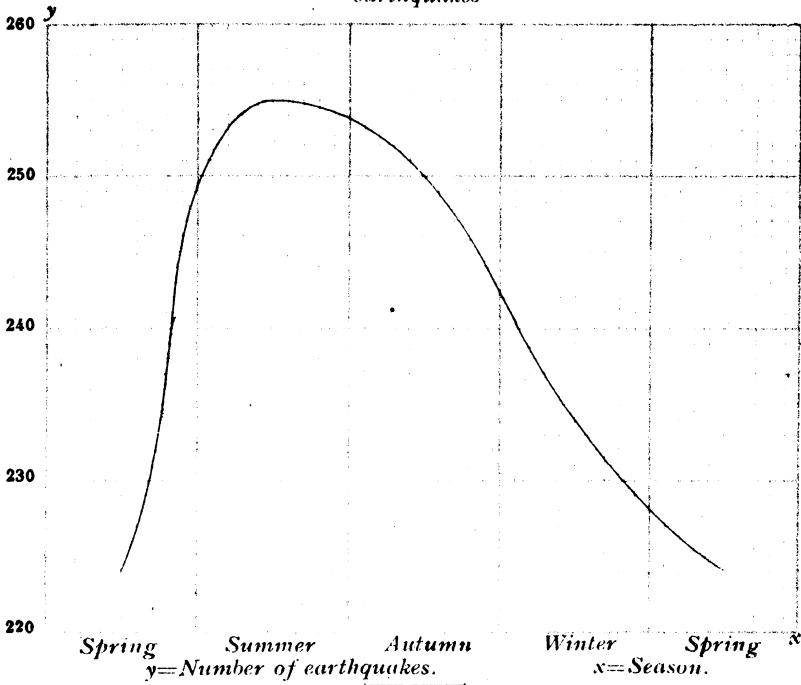


Fig. 2. Monthly Distribution of 90 destructive earthquakes

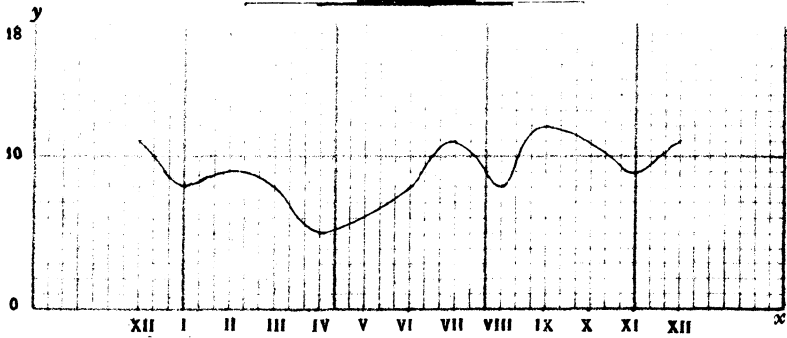
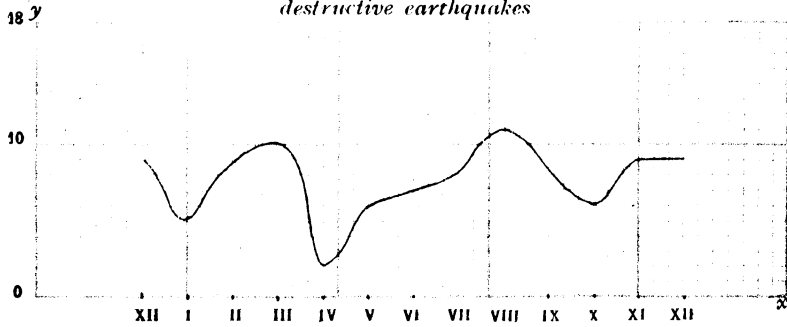
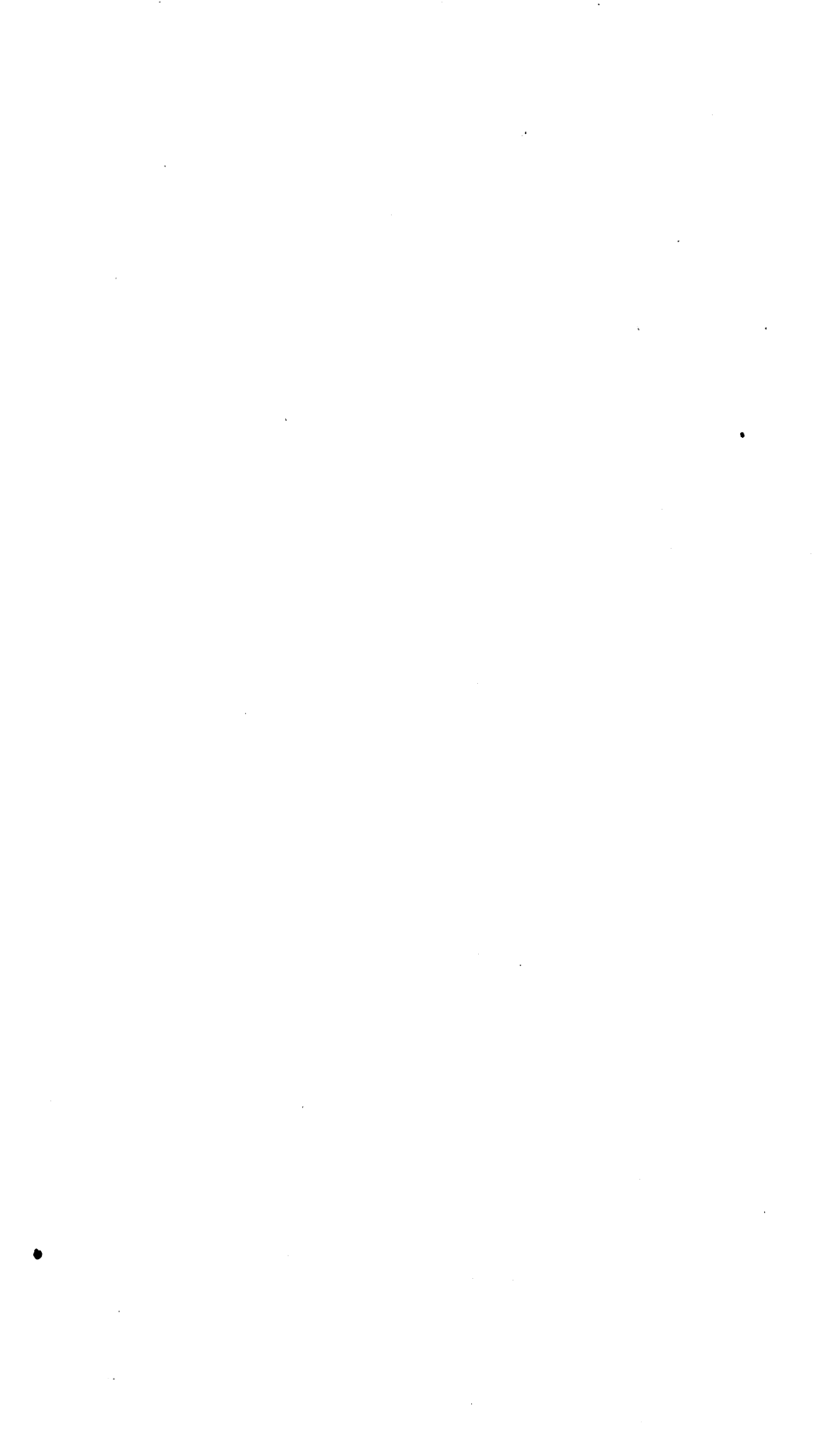


Fig. 3. Monthly Distribution of the eruptions in the Mayon volcano after the 17th century

$y = \text{Number of earthquakes}$

$x = \text{Month.}$



Provinces.	<i>i</i>	<i>s</i>	Provinces.	<i>i</i>	<i>s</i>
Ilocos Norte -----	3.7	18.3	Batangas -----	4.2	17.0
Cagayan -----	3.6	38.6	Tayabas -----	3.2	26.5
Abra -----	3.0	19.0	Camarines -----	3.9	27.9
Ilocos Sur -----	3.4	12.7	Albay -----	4.6	18.1
Nueva Vizcaya -----	3.4	22.3	Island of Panay -----	2.0	51.0
Benguet -----	2.0	21.6	Island of Negros -----	1.4	30.7
Union -----	2.0	19.7	Island of Samar -----	1.1	72.0
Pangasinan -----	3.0	19.0	Island of Leyte -----	0.7	61.9
Nueva Ecija -----	3.0	29.1	Zamboanga, Mindanao -----	1.4	52.0
Zambales -----	3.4	12.0	Surigao, Mindanao -----	9.8	21.5
Morong -----	3.1	14.3	Cottabato, Mindanao -----	2.0	73.7
Laguna -----	3.6	16.7	Dapitan, Mindanao -----	1.8	15.1
Manila -----	12.3	4.6			

Archipelago: $i = 53.5$, $s = 47.7$ miles.

There is some difference between our numbers and those found by Mr. de Ballore in his recent pamphlet, "De Seismen der Philippjnen," Amsterdam, 1901, because he took a very different period, and sometimes the single shock as unity, while we consider only the period running from the year 1880 to 1897, and take the earthquake day as our unit.

ANNUAL DISTRIBUTION.

From the foregoing Table I it may be seen that the earthquakes in the Philippine Islands are felt almost with the same frequency throughout the whole year, except that there is a very feeble maximum during the rainy season in the months of July, August, and September. We do not dare, however, to give such a maximum any value, even though we find the same result in the general series of earthquakes, as described in "La Seismologia en Filipinas." The reason is very clear, for during the above-mentioned months the rainy season is really confined to the western regions, while there is a maximum number of earthquakes even in the eastern regions.

The following Table II represents their distribution during the rainy season, the dry cold, and the dry hot season, the ratio of the number in the three epochs being 100 : 73 : 53.

If we consider the year divided into four ordinary seasons (TABLE III), then there is also a very slight maximum corresponding to the summer months, the maximum and the minimum numbers being in the ratio of 100 : 89.

TABLE II.—*Distribution of 962 earthquakes through three seasons.*

Seasons.	Number of earthquakes.
Rainy season:	
June -----	} 425
July -----	
August -----	
September -----	
October -----	
Dry cold season:	
November -----	} 313
December -----	
January -----	
February -----	
Dry hot season:	
March -----	} 224
April -----	
May -----	

TABLE III.—*Distribution of 962 earthquakes through four seasons.*

Seasons.	Number of earthquakes.
Autumn:	
September.....	} 249
October.....	
November.....	
Winter:	
December.....	} 234
January.....	
February.....	
Spring:	
March.....	} 224
April.....	
May.....	
Summer:	
June.....	} 255
July.....	
August.....	

The ninety destructive earthquakes reported in the foregoing pages are distributed through the year in the manner shown in the following table (IV).

It is often heard in the country that the volcanic activity of Mayon increases more or less according to the different seasons; thus, from the reports above and from the pamphlet "La Erupción del Volcan Mayon en 25 y 26 de Junio de 1897" we get the following Table V, where the numbers represent how many times the volcano, according to the reports we could obtain, has been in eruption since the seventeenth century, to which the first historical report belongs.

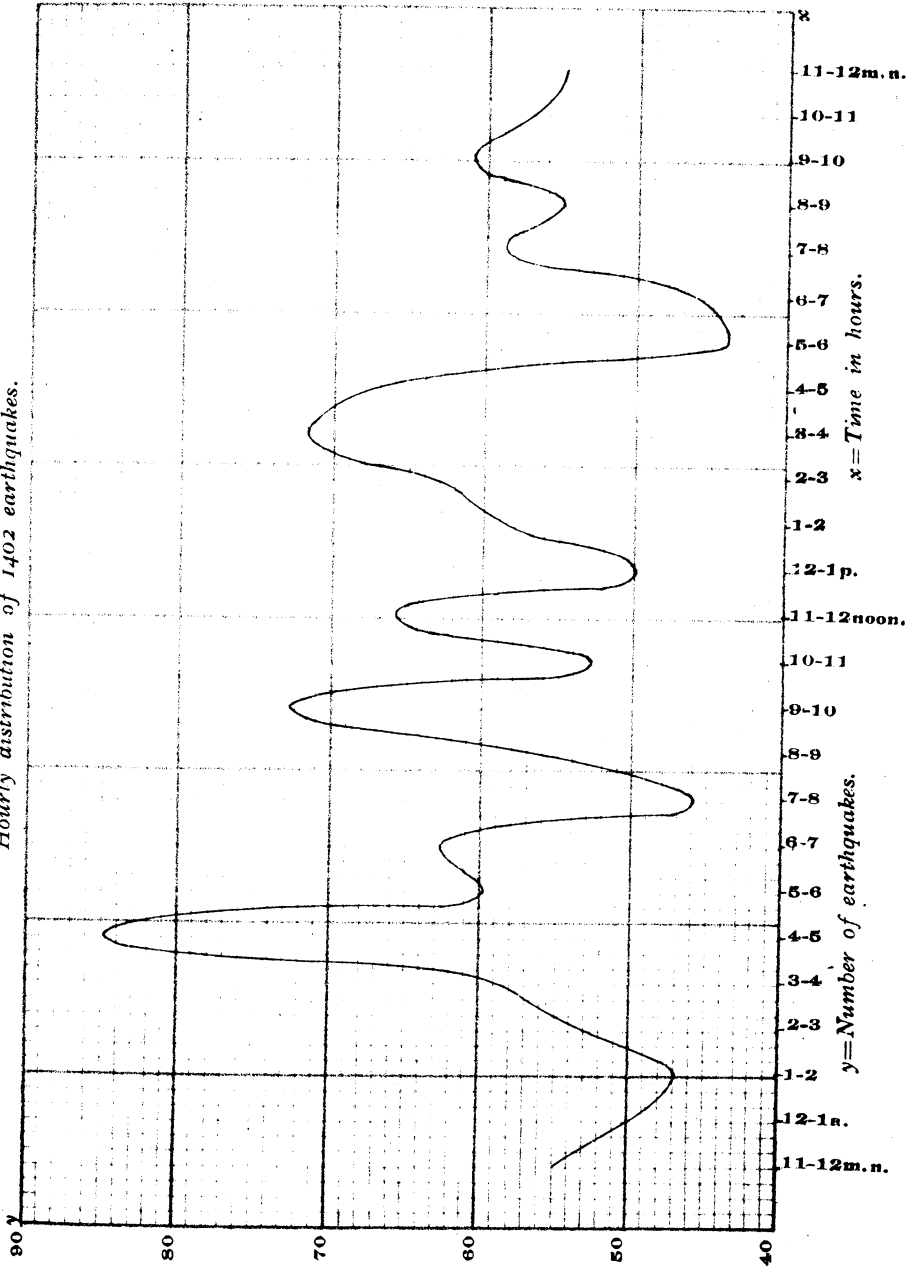
TABLE IV.—*Monthly distribution of 90 destructive earthquakes.*

Month.	Number of earthquakes.
I	5
II	9
III	10
IV	2
V	6
VI	7
VII	8
VIII	11
IX	8
X	6
XI	9
XII	9

TABLE V.—*Monthly distribution of the eruptions of the Mayon Volcano since the seventeenth century.*

Month.	Number of eruptions.
I	8
II	9
III	8
IV	5
V	6
VI	8
VII	11
VIII	8
IX	12
X	11
XI	9
XII	11

Hourly distribution of 1402 earthquakes.



The curves in Plate I, figures 1 and 2, represent graphically Table I; and in Plate II, figures 1, 2, and 3, the Tables III, IV, and V, respectively.

We can not conclude this chapter without saying a word about the distribution of earthquakes during the different hours of the day. It is often believed that earthquakes are less frequent between sunrise and sunset than between sunset and sunrise; however, in the Archipelago the ratio of the two numbers (day earthquakes and night ones) deduced from a series of 1,402 is 1.04, no more earthquakes being felt during night than during day. Their hourly distribution is graphically represented in Plate III. It shows three intervals in which the maximum number of earthquakes occur, namely, between 4-5, 9-10 a. m., and 3-4 p. m. The minimum number occurs within 1-2, 7-8 a. m., and 5-7 p. m. The maximum and minimum numbers are in the ratio of 100 : 52.

SEISMOMETRICAL OBSERVATIONS MADE AT THE CENTRAL OBSERVATORY, MANILA.

POSITION OF MANILA.

Manila is most advantageously situated for experiencing almost all the shocks radiating from the different centers of Luzon; it is no more than 35 miles north of the active Volcano Taal and a little more from the extinct ones Maquiling, Banajao, and Arayat. It stands on alluvial soil, probably covering the great tuff area stretching from the Gulf of Batangas northward throughout Cavite, Manila, and Bulacan Provinces and which has been considered as originally coming from Taal Volcano. This deep layer of tuff appears as an outcrop in the alluvium east and northeast of Manila. The surface ground of the capital is low and soft and traversed in all directions by many creeks or streams called esteros, and from east to west by the Pasig River, which flows into the bay after a sinuous course of some 18 miles. This river flows from the Laguna de Bay through five branches, and forms its outlet. The Observatory is situated about a mile southeast of the Walled City. Up to the year 1882 the standard seismic instruments used were simple seismometric pendulums and since that date the improved Cecchi seismograph.

NUMBER OF EARTHQUAKES.

The total number of earthquakes registered at the Observatory by the standard seismograph during the eighteen years between 1880 and 1897 is 221, as may be seen in the following table:

TABLE VI.

Year.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum.
1880	0	0	0	1	0	0	6	2	1	1	2	0	13
1881	0	1	0	0	2	0	2	2	3	4	1	2	17
1882	1	0	2	3	2	2	6	0	5	2	3	0	26
1883	0	4	0	1	1	1	3	2	0	0	0	0	12
1884	1	0	1	1	1	0	0	0	0	3	1	2	10
1885	0	0	1	2	3	0	1	1	0	1	6	0	15
1886	2	0	0	0	1	3	1	1	1	0	0	0	9
1887	0	0	2	1	0	1	1	0	0	1	0	1	7
1888	0	2	0	0	1	0	0	2	0	0	0	3	8
1889	0	0	0	1	3	1	0	0	0	0	0	1	6
1890	1	1	1	2	3	3	0	1	0	0	0	1	13
1891	0	0	1	1	2	1	0	0	3	2	0	1	11
1892	0	1	8	3	2	1	2	1	0	1	2	2	23
1893	2	1	1	3	0	0	0	0	1	1	1	0	10
1894	0	0	0	3	0	0	0	2	0	0	1	0	6
1895	1	3	0	1	3	0	2	2	0	3	1	0	16
1896	3	0	0	0	0	1	0	0	1	0	0	0	5
1897	2	0	1	1	2	0	0	3	2	1	1	1	14
Total	13	13	18	24	26	14	24	19	17	20	19	14	221
Means	0.72	0.72	1.00	1.33	1.44	0.78	1.33	1.05	0.94	1.11	1.05	0.78	12.3

Fig. 1. Monthly Distribution of 211 earthquakes registered at the central Observatory Manila.

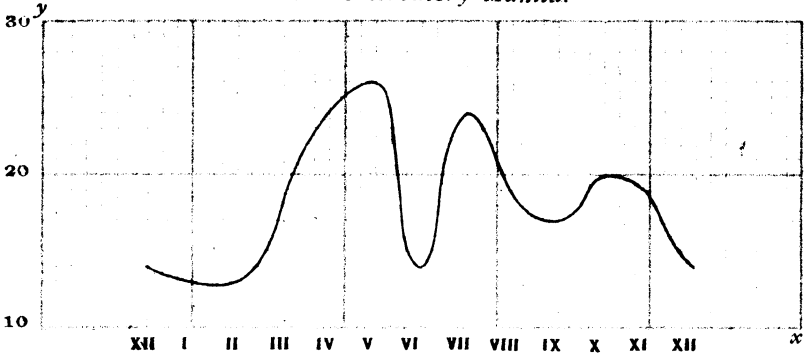


Fig. 2. Seismic activity at Manila (Between 1880 and 1897)

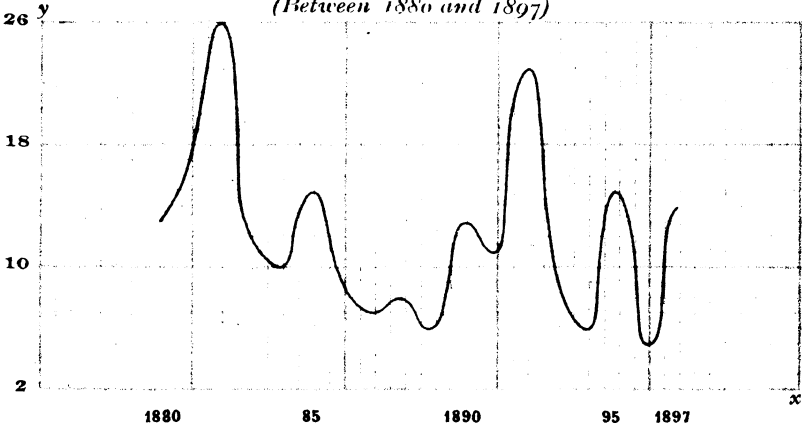
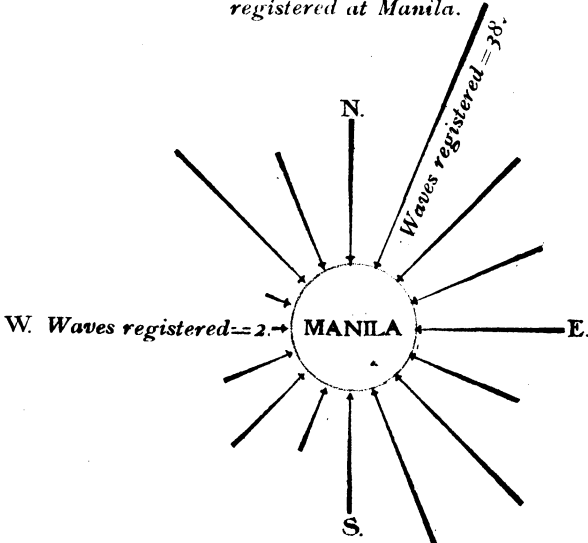


Fig. 3. Diagram showing the directions of 276 seismic waves registered at Manila.



From the above table we see that the average annual number of earthquakes at Manila is twelve. In the first six years, with the exception of 1884, the number was equal or greater than the average, while in the four following years it was constantly below the average. After the year 1890 the number varies, the minimum being in 1896.

This table shows, too, that neither the annual nor the monthly distribution of earthquakes at Manila agrees with the corresponding table of their distribution for the whole Archipelago, as can be seen by comparing the curves on Plate I with those on Plate IV.

The average monthly number of earthquakes at Manila is 1.00. The number in each of the first six months of the year, spring and summer, or hot dry and rainy season, with the single exception of June, is greater, while that in each of the six autumn and winter months, or the end of the rainy and the cool dry season, is ordinarily less. The maximum number occurs in May and the minimum in January and February, the former being just double that of the latter.

DIRECTION OF THE SEISMIC WAVES AT MANILA.

Since the year 1880, 276 greater waves have been registered, distributed among 221 perceptible earthquakes. The directions of the waves correspond to the sixteen main directions of the compass and are summarized in the following table. The number of the oscillations registered are expressed after the corresponding direction.

TABLE VII.

First quadrant.	Number.	Second quadrant.	Number.	Third quadrant.	Number.	Fourth quadrant.	Number.
N-S	19	E-W	20	S-N	16	W-E	2
NNE-SSW	38	ESE-WNW	16	SSW-NNE	9	WNW-ESE	4
NE-SW	23	SE-NW	24	SW-NE	14	NW-SE	25
ENE-WSW	19	SSE-NNW	22	WSW-ENE	10	NNW-SSE	17
Total	99		82		49		48

The above table shows that the directions in which the shocks are more frequently felt at Manila are north-northeast, northwest, and southeast, the maximum number corresponding to the first direction. In this direction we find not only the center of Nueva Vizcaya and the one in the northeast end of the island, but there also seems to be a closer one to the east-northeast. This can be called the Manila center, for its shaken area comprises ordinarily the Provinces of Manila, Morong, Bulacan, and La Infanta. All these centers are very active, but only one, namely, that lying in the east-northeast, seems, as far as our present knowledge goes, to be dangerous for Manila. The destructive waves experienced on the 18th of July, 1880, can be very probably ascribed to that center. Southeastward lie the powerful volcanic centers Maquiling, Banajao, and the volcanoes of Albay and Sorsogon. The latter do not represent any danger for Manila; their waves hardly retain any

force after crossing along the mountain ranges of Camarines. Not far to the southeast about the Laguna de Bay is probably the seismic center from which the destructive waves felt on the 20th of July, 1880, radiated, those felt on the 14th radiating from a more distant eastern center. Besides this, the waves proceeding from the southern center reach Manila a little inclined to the southeast, thus increasing the number of waves coming from that direction. Since the year 1880 there are many instances, for example, that of the 15th of December, 1901, of earthquakes quite violent or destructive southward in Batangas and the Island of Mindoro, and very probably belonging to the Taal center. These were felt at Manila in the form of large, slow waves, inclined either to the southeast or to the southwest. The smallest number of waves are those from the west and west-northwest; this seems to suggest that there is no seismic center westward under the sea, such as is very probably the case at the western edge of Mindanao. Besides, no tidal wave has ever been mentioned in connection with the destructive earthquakes of Manila. The investigation of the causes to which we can attribute the above deviations of the seismic waves would carry us too far from our present purpose, so we remit the question to a more opportune occasion. The great number of waves proceeding from the northwest might urge us to consider the centers of Pangasinan and Ilocos as independent from those of Nueva Vizcaya and Cagayan were it not for the fact that such a direction has sometimes been registered even in earthquakes which evidently have their epicentric area in the north.

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